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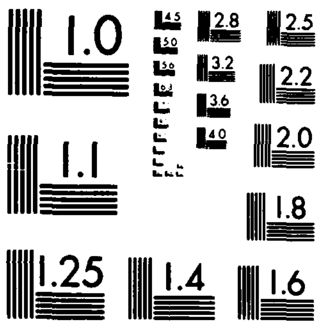

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Statistical Analysis of Helicopter Pilot Performance During Instrument Flight Across Repeated Flights

Annual Report

Dennis J. Folds
Gary W. Yunker
T. Allen Smith

December 15, 1982

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The visual performance of helicopter pilots during simulated extended operations was examined in terms of methodological issues and statistical analysis. Visual performance data collected, but not analysed, during a simulated extended operations study by investigators at the U.S. Army Aeromedical Research Laboratory (USAARL), Ft. Rucker, Alabama, served as the data base. The dependent variables associated with visual performance during IFR were factor analysed and it was concluded that the data could be largely accounted for by two orthogonal factors: measures of the relative importance of an instrument during a flight

Abstract Cont.

segment and measures of the central tendency of the fixation times. Several findings reported in USAARL Report No. 78-6 were replicated in this study but the three zone/cost factor theory offered in that report was not supported empirically. Statistical analyses revealed several differences in the use of the instruments as a function of flight maneuver (instrument take-off, cruise flight, and instrument landing), but no differences that could be attributed to the effects of fatigue.

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Introduction

Army aviation is a vital element in the conduct of surge and sustained operations by the U.S. Army. The detrimental impact of fatigue on aircrew effectiveness has long been an area of concern for the aviation research community. This concern has increased as a function of the modern tactical requirements of around-the-clock operations under all meteorological conditions. In adverse weather situations Army helicopter pilots must fly under instrument flight rule (IFR). The IFR flight condition has been suggested to be one of the most important contributing factors to the problem of aviator fatigue.[1]

In response to the many questions surrounding the extended operation requirements envisioned for Army aviators during a conflict situation such as another ground war in Europe, investigators at the U.S. Army Aeromedical Research Laboratory (USAARL), Ft. Rucker, AL., conducted a research project designed to simulate extended operations. Six volunteer subjects flew various mission profiles in a flight simulator over a one week period. The one week period consisted of a pre-test day, five test days, and a post-test (recovery) day. As part of the routine observed during the five test days, each day a subject performed a set of standard flight maneuvers while wearing the National Aeromedical Corps eye-mark equipment used by USAARL investigators to record the visual behavior of aviators.[2] The maneuvers were instrument take-off (ITO), cruise flight (CRUISE) and instrument landing (ILS). The maneuvers were performed at approximately the same time each day to reduce any within-day effect that might be present. The experimental design for the visual performance data was therefore a two-factor (maneuvers and days), repeated measures design. The raw data

were reduced and verified by USAARL personnel in accordance with in-house procedures. The analysis of the resulting summary statistics for each flight segment is the focus of the present research.

BACKGROUND

An initial examination of the visual behavior of helicopter pilots during instrument flight was reported by Simmons, Lees, and Kimball[3]. The principal findings of that report may be summarized as follows:

1. The vast majority of visual time during instrument flight is spent fixated on seven cockpit instruments: the altimeter (ALT), vertical speed indicator (VSI), attitude indicator (AH) radio magnetic indicator (RMI), omnibearing selector (OBS) airspeed indicator (AS), and turn and bank indicator (T&B).
2. The AH and RMI *combined* account for over one-half of total visual time, with the attitude indicator being used the most.
3. The mean dwell time for instruments with simple pointer systems such as the ALT, AS, and VSI was 400 to 500 milliseconds (msec) while more complex instruments such as AH and RMI required 500 to 600 msec.
4. The objective visual performance data greatly differed from the pilots' opinion of the importance of various instruments.

In the same report the authors offer a novel approach to the description of the visual workload of helicopter pilots. The major points of their "three zone/cost factor" theory are as follows:

1. The instrument panel may be divided into the three zones. Zone 1 consists of the AH, RMI, and T&B. This zone contains the information necessary to maintain the basic stability of the aircraft. Zone 2 consists of the ALT, VSI, and AS. This zone provides detailed information about current aircraft status. Zone 3 consists of all other areas, including the OBS. The information in the zone is essential only in special requirement situations. Otherwise Zone 3 is monitored on an "as time allows" basis.
2. The "cost factor" of each zone (with respect to visual workload) may be calcualated as follows:
   (<u>percent of total time spent in the zone + percent of total fixations occuring in the zone</u>) divided by 2.
3. The cost factor of Zone 1 during a particular flight segment is an index of the amount of the pilot's attention necessary to maintain the basic stability of the aircraft.
4. ITO appears to require the most and ILS the least attention to Zone 1. The cost of the zone during other maneuvers is somewhere in between these two extremes.

The primary intent of the zone/cost factor approach is to simplify the quantification of the visual performance of helicopter pilots. The computation of the cost factor variable combines the two basic measures of visual performance (number of fixations and total dwell time) into a single value which represents the "cost" of a particular area during a flight segment. Dividing the visual field into three zones instead

of the twenty to thirty instruments and guages (depending on the particular cockpit) and computing the cost factor for each zone allows a pilot's visual behavior during a particular flight segment to be represented by three values.

RESEARCH QUESTIONS ADDRESSED IN THE PRESENT RESEARCH

The findings of Simmons, Lees, and Kimball summarized above and the experimental design employed in the collection of the data analysed in the present research suggest a number of research questions. These questions may be divided into three categories: replication of certain findings presented by Simmons, Lees, and Kimball, methodological considerations, and statistical analyses. The research questions are specifically stated below:

<u>Replication</u>

1. Assessment of the relative amount of visual time accounted for by the seven primary instruments identified by Simmons, Lees, and Kimball.
2. Assessment of the preeminence of the AH and RMI during instrument flight as described by Simmons, Lees, and Kimball.
3. Comparison of the mean dwell times of several instruments obtained by Simmons, Lees, and Kimball with the mean dwell times for the same instruments in the present research.

<u>Methodological Considerations</u>

4. Examination of the several dependent variables computed from raw visual performance data in order

to assess redundancies and select variables for further analysis.

5. Assessment of the three zone/cost factor theory by empirical procedures.

Statistical Analyses

6. Analyze differences in visual performance due to maneuver.
7. Analyze differences in visual performance due to days.
8. Analyze differences in visual performance due to a maneuver by day interaction.

METHOD

Procedures

The replication questions (1-3) were addressed by comparing summary statistics obtained in the present research with the findings reported by Simmons, Lees, and Kimball. The methodology questions (4 and 5) were addressed by factor analysis using the varimax procedure in factor rotation. The statistical analysis questions (6-8) were addressed by the analysis of variance (ANOVA) for a two-factor, repeated measures design.[4] Follow-up contrasts among means for significant $\underline{F}$ values were performed using a simple t-test for related measures.

RESULTS

Research Question 1. It was found that the seven instruments identified by Simmons, Lees, and Kimball accounted for approximately 80% of total visual time in the present study. The other eighteen instruments/guages in the simulator cockpit accounted for approximately 3%, all other areas ("Rest") accounted for about 7%, and the remaining

10% was transition time (See Table 1). Since "rest" and transition are indiscriminate areas and the other eighteen instruments accounted for only 3% of visual time, it seems that the seven primary instruments represent the essential visual tasks of the pilot during IFR. The previous findings of Simmons, Lees, and Kimball in regard to this research question were confirmed.

Research Question 2. It was found that the AH and RMI combined did in fact account for a great deal of visual time, although the actual percent of total time (46.9%) was slightly less than the "over 50%" reported by Simmons, Lees, and Kimball. Their observation that the AH was used more than the RMI was not confirmed by the data in the present study. As shown in Table 1, the RMI accounted for slightly more visual time than the AH (24.5% to 22.4%). However, when the data are expressed in terms of percent of total fixations instead of percent of total time, the AH slightly outranks the RMI (26% to 25%). The differences between these two measures are due to the longer mean dwell-time associated with the RMI (see below). Considering both of the variables, it appears that the RMI and AH were roughly equal in importance in the present study.

Research Question 3. The mean dwell times for each of the seven primary instruments are presented in Table 2. The general observation of Simmons, Lees, and Kimball that the more complex instruments have higher, i.e. longer, mean dwell times than the instruments with simple pointer systems is confirmed by these results. However, the actual values of the mean dwell times tended to be slightly higher than the ranges reported by Simmons, Lees, and Kimball. They reported that

simple instruments such as the ALT, AS, and VSI had mean dwell times in the 400-500 millisecond range; in the present study only the mean dwell time for the T & B fell in that range. The value for the ALT, AS, and VSI were slightly higher than 500 msec in the present study. They also reported that more complex instruments such as the AH and RMI had mean dwell times in the 500-600 msec range. In the present study, the mean dwell time for the AH fell within that range whereas the mean dwell time for the RMI was over 600 msec and the mean dwell time for the OBS was nearly 700 msec. Note that the difference between the mean dwell time for the VSI, an instrument with a simple pointer system, and the AH, a more complex instrument, was only 20 msec in the present study.

Research Question 4. The seven dependent variables presented in Table 3 were factor analysed for each of the primary instruments. Six of the seven instruments (the OBS being the exception) returned virtually identical two-factor solutions. The rotated solutions are presented in Table 4. Examination of the rotated solutions revealed that four variables (percent of looks, scan rate, percent of time, and cost factor) had extremely high loadings on factor 1 while mean dwell time and median dwell time had high loadings on factor 2. Since variables which are highly correlated (and therefore load on the same factor) are largely redundant, and conceptually similar, the two variables with the highest average loadings on factor 1 and factor 2 (scan rate and mean dwell time, respectively), were selected for further analysis.

Research Question 5. The factor analysis mentioned above also served to address the computation of the cost factor variable.

Cost factor is the average of two variables which are highly c in the present data base. Therefore, the examination of the c variable has no particular advantage, nor disadvantage, over e tion of percent of looks, scan rate, or percent of time.

The division of the pilot's visual field into three zones shown in Table 5, was not supported by factor analysis. The s values for each of the seven primary instruments during each f segment were factor analysed to determine the grouping of the struments which best accounted for the variance of the scan ra varimax procedure used in factor rotation seeks to maximize th of each variable (instrument) on one of the factors, i.e., eac ment has a high loading on one factor and near zero loadings c factors. This analysis resulted in a three-factor solution wh accounted for only 76% of the total variance. The rotated sol presented in Table 6. The instruments which had high loadings factor 1 were the VSI, AH, and OBS. The sign of the loading f AH is negative. Further examination of the data revealed that negative loading of the AH is largely due to subject differe the performance of the ILS maneuver. This issue will be addre The instruments with high loadings on factor 2 are the RMI anc The ALT and AS had high loadings on factor 3. Although there similarity between the factors and the zones shown in Table 5, are also major differences. It is not accurate to state that findings of the present research somehow disproved the zone th however, it is accurate to state that the theory was not suppc empirically.

Research Questions 6, 7, & 8. Based on the findings regarding questions 1, 4, and 5 above, the appropriate ANOVA was performed to assess the effects of maneuvers, days, and the maneuver by day interaction on the mean dwell times and scan rates for the seven primary instruments. Therefore, there were fourteen (seven instruments times two variables) ANOVAs performed. None of these fourteen analyses revealed any significant effects due to days or the maneuver by day interaction. All significant F-ratios were associated with the maneuver effect.

The analyses of the scan rate data reveal that five of the seven instruments were used significantly more on certain maneuvers than in others. Only the AH and RMI showed no differences. The ANOVA tables for the five significant tests are presented in Tables 7-11. Since there were no significant day or maneuver by day interaction effects, the subsequent contrasts of means were performed by collapsing the data across days and computing the true scan rate of each instrument for each subject across the five test days. With the data expressed in this form the contrasts of means was accomplished by doing a series of simple t-tests for related measures. The significant contrasts are summarized in Table 12.

Identical tests were performed on the mean dwell time values. These tests revealed that the mean dwell time for both the OBS and VSI were higher during ILS than during the other two maneuvers. The ANOVA tables for these two tests are presented in Tables 13 and 14. The other five instruments showed no differences in mean dwell time between maneuvers.

SUBJECT DIFFERENCES

Further examination of the data revealed differences between subjects that affect the interpretation of the results presented above. A certain amount of variation between subjects is not only expected but is also desirable. The visual behavior of aviators during flight is complex and there is probably no single "correct" way of performing the visual tasks. Inherent limitations due to the limited availability of volunteer subjects, time, and incurred expenses generally result in a small number of subjects. Experimenters conducting research projects such as this one must endeavor to obtain a representative sample of the population of aviators. When the data later reveal marked differences between subjects, experimenters are left to ponder whether a homogeneous population was in fact sampled or whether the variation within the population is so broad that the employment of such a small N can adequately sample the population. The presence of one or perhaps two deviant subjects poses relatively minor problems in data interpretation. However, in areas where subjects exhibit large and consistent differences in the performance of the behavior in question, interpretation of results is often quite difficult. Summary statistics such as these presented in Table I may be mere statistical artifacts, i.e., they may not represent the way subjects tended to perform, but instead represent the midpoint between two drastically different ways of performing the task. There were two particular areas of difference between subjects that are especially pertinent to the discussion which is to follow. These two areas of differences are explored below.

As mentioned above (Results, Question 5), the negative correlation between the AH and the OBS is largely due to differences between subjects. Table 15 shows the % TT during ILS spent fixated on the AH, RMI, and OBS for each subject. Note that the values for the RMI were quite stable; only one value is outside the 20%-25% range. However, subjects greatly differed on the percent of time devoted to the AH and the OBS. Although the total values, collapsed across subjects, for the AH and the OBS are relatively close (19.1% and 21.2%, respectively), only subject 5 used the two instruments in a balanced manner. Subjects 1, 2, and 3 used the OBS far more than the AH. Subjects 4 and 6 used the AH far more than the OBS. Whether these differences reflect two equally successful strategies in the performance of the maneuver, differences in training or experience, or some other factor is unknown. It is apparent, however, that these differences affected the factor analysis performed to address Question 5.

Another area of subject differences which is important has to do with the performance of the ITO maneuver. This maneuver, according to the zone theory, is the maneuver in which monitoring of Zone 1 instruments (AH, RMI, T&B) is most critical. Table 16 presents the %TT spent fixated on each of these instruments, and the total for zone 1, during ITO. Three subjects used the T&B less than five percent of total time while another subject used the instrument over fifteen percent of total time. The three subjects that used the T&B less than 5%TT differed from one another in their use of the AH and the RMI; one favored the RMI, one favored the AH, and the third used the AH and RMI in a relatively equal way. The point is that since subjects greatly differed in the use of the instruments within the zone, the

value for the zone as a single entity is an artifact and actually reveals very little about the subject's behavior. (To illustrate this point, compare the values for subjects 3 and 4 in Table 16.)

Differences between subjects affected the analyses performed in this project in various ways. The ANOVAs possibly become more liberal tests in that the the large sum-of-squares value for the untestable subject effect are subtracted in the calculation of the error terms, perhaps resulting in inflated values of F. The factor analyses reflect the subject differences and are therefore difficult to generalize to the aviator population. The major problem posed by the subject differences, however, is not their effect on the statistical analyses but rather their effect on the confidence which may be placed in the representativeness of the results.

DISCUSSION

Research Question 1, 2 & 3. The findings of Simmons, Lees, and Kimball with respect to these questions were largely confirmed. The minor differences were probably due to differences in the two studies. The data used in the former study were collected in-flight whereas the data in the present study were collected in a flight simulator. The mission profiles used in the former study included climbing, descending, and level turns in addition to the three maneuvers performed in the present study. The summary statistics for the data in the present study reflect not only important subject differences, as discussed above, but also the pre-eminence of the ILS maneuver in the present study. The ILS accounted for approximately 62% of total time with ITO and CRUISE accounting for 15% and 23% respectively. In spite of these differences, the general nature of

the findings of the former study was confirmed.

Research Question 4. The emergence of scan rate and mean dwell time as the variables which largely account for the variance in the several dependent variables is potentially the most useful of all the findings of this project. The high positive correlations among scan rate, percent of total time, percent of looks, and cost factor indicate that they are largely measures of the same phenomenon in visual behavior. It is important that these relationships be assessed in other data in order to confirm or deny their generality. If the relationships are confirmed, analysis of similar data in the future can be simplified and made more uniform. The presently complex task of describing visual behavior of aviators will be greatly reduced if these relationships are confirmed.

Research Question 5. Although the grouping of the instruments into the zones shown in Table 5 was not supported empirically, the grouping supplied by the factor analysis accounted for only 76% of the variance and is admittedly influenced by differences between subjects. There is no implication that the zone theory be discarded, but there is a suggestion that the theory be further tested. The values in Table 16 illustrate the primary problem with the zone values: knowledge of the value for the zone imparts very little information about visual behavior within the zone. The validity of the theory on this point rests on one crucial question: does it matter which instruments within the zone are given visual time? If the collective monitoring of the instruments is critical while the specifics are not critical, then the theory may be valid. If the converse is true, the value for the zone may conceal important differ-

ences. According to the zone theory, the instruments within Zone 2 (ALT, AS, VSI) present "quality flight management" information which is monitored only when the monitoring of Zone 1 is not critical. Projecting this line of thought, monitoring of Zone 2 should be highest during cruise flight since ITO requires more effect in Zone 1 and ILS poses a navigation task which requires use of the OBS - a Zone 3 instrument. This observation is true for the ALT and the AS, but not for the VSI. In fact, the VSI was used almost twice as much during ILS than during ITO or CRUISE (see Table 17). Zone 3 consists of all visual areas not included in Zones 1 and 2. The primary problem with this arrangement is the inclusion of the OBS in the zone. Examination of the percent of time spent in Zone 3 indicates that during ILS the monitoring of Zone 3 becomes critical. This observation is misleading in that it is only the monitoring of one instrument in the zone - the - OBS - which becomes critical during the ILS. Other instruments within the zone actually received only about one half the visual time that they received during ITO or CRUISE (again, see Table 17). The intent of the theory - to simplify the task of describing visual behavior - is commendable. However, the lack of empirical support for the grouping arrangement, along with the instances cited where the zone values may be misleading, suggests that caution be taken in analysis of the zone values.

Research Questions 6, 7 & 8. The observed differences between maneuvers were not surprising. Just as automobile drivers perform different tasks in different situations such as cruising down the freeway, parking, and merging onto crowded streets, helicopter

pilots perform different tasks during different flight maneuvers. It is not surprising that certain instruments are more important in some maneuvers as opposed to other maneuvers. In general, analyses of the scan rates revealed no significant differences in the use of the AH and RMI, the two prominent instruments, while the use of the OBS and VSI increased during ILS and the use of the ALT, AS, and T&B decreased during ILS. The finding that the mean dwell time of the OBS was higher during ILS than during the other maneuvers is also not surprising since the instrument presented no information to the pilot during ITO or CRUISE. The OBS received only occasional glances during these maneuvers and there was nothing to "read" on the instrument. During ILS, however, the OBS was not only operational but essential to the performance of the maneuver. When the effect of the occasional glances during the other maneuvers are removed, the mean dwell time for the OBS rises from 697.0 msec (Table 2) to 713.7 msec. The higher mean dwell time for the VSI during ILS is more puzzling. One possible explanation is that during ILS it is more important for the pilot to determine precisely at what rate the aircraft is decending, whereas during other maneuvers the instrument is read only to confirm a less specific range of the rate of change. If this explanation is correct then mean dwell time is not only a measure of the complexity of the instrument's design but also of the degree of accuracy required by the flight situation.

Differences between maneuvers or between subjects are interesting and need to be studied by the research community. However, the pressing research question of practical benefit to the military

community is the effect of the simulated extended operations (the Day effect) on the ability of helicopter polots to safely and successfully fly. None of the statistical methods employed in this project revealed significant differences across days of flight. The absence of significant results does not mean that pilots did not become fatigued. It may be that the considerable variance across days obscured the real effect of fatigue on the visual behavior of the subjects. It may also be that fatigue, if in fact present, did not affect the way the subjects gathered visual information. Examination of other types of data collected in the larger study may reveal changes due to fatigue.

CONCLUSIONS

This study was undertaken to analyze the visual performance data gathered during simulated extended operations using a variety of analytical techniques. Some conclusions may be noted from the results.

1. The findings of Simmons, Lees, and Kimball, cited above, which were relevant to the data examined in the present study were generally confirmed.
   a) The primary visual tasks of helicopter pilots during IFR are concentrated on seven instruments: the ALT, VIS, AH, RMI, OBS, AS, and T&B.
   b) The AH and RMI collectively account for nearly one half of visual time during IFR flight.
   c) Gauges such as oil pressure, exhaust temperature, and fuel received very little visual time. The implication is that malfunctions reflected by the gauges may have a low probability of early detection.

d) Instruments with simple pointer systems were associated with somewhat lower mean dwell times than were more complex instruments.

2. The dependent variables computed from the raw data generally measure two independent phenomena: Scan rate, percent of total time, percent of looks, and cost factor are measures of the relative importance of an instrument during a flight segment whereas mean and median dwell time are measures of the complexity and perhaps the required precision of reading the instrument.

3. The cost factor/zone theory offered by Simmons, Lees, and Kimball lacks empirical support in these data and should be further tested.

4. The two most prominent instruments, the AH and the RMI, showed no significant difference in use when compared across maneuvers. The remaining five (of the seven listed above) instruments did show varying degrees of relative importance between compared maneuvers.

5. No significant difference in visual performance could be attributed to fatigue.

REFERENCES

1. Perry, I.C., Ed. Helicopter aircrew fatigue. AGARD Advisory Report No. 69. London: Harford House. Advisory Group for Aerospace Research and Development, May 1974.

2. Simmons, R., Kimball, K., and Diaz, J. Measurement of aviator visual performance and workload during helicopter operations. (USAARL Report No. 77-4) Ft. Rucker, AL: U.S. Army Aeromedical Research Laboratory, December 1976.

3. Simmons, R., Lees, M., and Kimball, K. Visual performance/workload of helicopter pilots during instrument flight. (USAARL Report No. 78-6) Ft. Rucker, AL: U.S. Army Aeromedical Research Laboratory, January, 1978.

4. Myers, J. Fundamentals of Experimental Design Allyn and Bacon, Inc. Boston, Mass. 1979

TABLE 1

Percent of Total Time for Each Instrument

INSTRUMENT	ABBREVIATION	% TOTAL TIME
Altimeter	ALT	4.0
Vertical Speed Indicator	VSI	5.4
Artificial Horizon	AH	22.4
Radio Magnetic Indicator	RMI	24.5
Omni-bearing Selector	OBS	13.6
Airspeed Indicator	AS	5.4
Turn & Bank Indicator	T&B	3.7
Compass	CMPS	*
Clock	CLK	.7
Fire Warning Light	FIRE	*
Tachometer	RPM	.6
Torque	TQ	.5
Gas Producer	GSPD	.3
Exhaust Gas Temperature	EXTP	.1
Master Caution Light	WING1	*
Fuel Gauge	FUEL	.2
Oil Gauge	OIL	.2
Transmission Gauge	TRNS	.2
Electrical Load Meters	ELEC	.1
Co-pilot's Altimeter	2ALT	*
Co-pilot's VSI	2VSI	*
Co-pilot's AH	2AH	*
Co-pilot's RMI	2RMI	*
Co-pilot's AS	2AS	*
Co-pilot's OBS	2OBS	*

* - Less than one half of one percent

TABLE 2

MEAN DWELL TIMES For the Seven Primary Instruments (milliseconds)

OBS	697.0
RMI	620.0
AH	555.0
VSI	535.4
AS	511.2
ALT	507.9
T&B	429.8

TABLE 3

Dependent Variables for Visual Performance Data

ABBREVIATION	NAME	EXPLANATION
1. #LKS	number of looks	total number of eye fixations
2. %LKS	percent of looks	#LKS/total #LKS
3. MEAN	mean dwell time	average duration of fixations
4. MED	median dwell time	median of the dwell times
5. RATE	scan rate	how often the area was fixated
6. %TT	percent of total time	percent of visual time spent fixated on the area
7. CF	cost factor	(%LKS + %TT)/2; percent of workload

TABLE 4

Factor analysis of Seven Department Variables

		VARIABLE						
Instrument	Factor	#LKS	%LKS	MEAN	MED	RATE	%TT	CF
ALT	1	.740	.977	.094	.154	.975	.922	.96
	2	-.193	-.221	.893	.862	-.301	-.022	-.11
VSI	1	.837	.931	.258	.359	.947	.892	.91
	2	.236	.336	.945	.902	.230	.395	.36
AH	1	.651	.953	.164	.179	.974	.932	.95
	2	.397	.242	.913	.917	-.069	.322	.25
RMI	1	.505	.976	.005	.099	.965	.942	.97
	2	-.116	.138	.957	.927	-.082	.249	.19
AS	1	.614	.958	.152	.281	.968	.936	.95
	2	.219	.196	.959	.928	.089	.277	.24
T&B	1	.824	.983	.081	.147	.989	.962	.99
	2	.177	.087	.964	.959	.017	.162	.12
Averages	1	.711	.963	.125	.203	.969	.931	.95
	2	.184	.129	.938	.915	-.019	.230	.17

Average variance accounted for by Factor 1

TABLE 5

Three Zones of the Pilot's Visual Field

Zone 1	AH
	RMI
	T&B
Zone 2	ALT
	VSI
	AS
Zone 3	OBS
	All other instruments
	All other visual areas

TABLE 6

Factor Analysis of the Seven Primary Instruments

	ALT	VSI	AH	RMI	OBS	AS	T & B
Factor 1	.093	.843	-.781	.348	.791	-.355	-.108
Factor 2	-.059	.116	.161	.783	-.183	-.027	.918
Factor 3	.910	-.173	.177	-.296	-.325	.714	.107

TABLE 7

ANOVA Tables for Scan Rate

SV	df	SS	MS	F	P less than
Total	89	1512.259	-	-	-
Maneuvers	2	406.691	203.345	13.51	.05
Days	4	56.032	14.008	0.78	N.S.
Subjects	5	157.088	31.418	-	-
Man. x Day	8	67.265	8.408	1.06	N.S.
Man. x Sub.	10	150.543	15.054	-	-
Day x Sub.	20	357.086	17.854	-	-
Man. x Day x Sub.	40	317.553	7.939	-	-

TABLE 8

ANOVA - VSI Scan Rate

SV	df	SS	MS	F	p less than
Total	89	1444.954	-	-	-
Maneuvers	2	172.142	86.071	7.76	.05
Days	4	17.003	4.251	0.18	N.S.
Subjects	5	211.326	42.265	-	-
Man. x Day	8	16.075	2.009	0.18	N.S.
Man. x Sub.	10	110.860	11.086	-	-
Day x Sub.	20	462.886	23.144	-	-
Man. x Day x Sub.	40	454.661	11.367	-	-

TABLE 9

ANOVA - OBS Scan Rate

SV	df	SS	MS	F	P less than
Total	89	8275.027	-	-	-
Maneuvers	2	4889.152	2444.576	32.48	.05
Days	4	20.001	5.000	.14	N.S.
Subjects	5	493.242	98.648	-	-
Man. x Day	8	54.326	6.791	0.20	N.S.
Man. x Sub.	10	752.638	75.264	-	-
Day x Sub.	20	725.610	36.280	-	-
Man. x Day x Sub.	40	1340.059	33.501	-	-

TABLE 10

ANOVA - AS Scan Rate

SV	df	SS	MS	F	P less than
Total	89	2476.259	-	-	-
Maneuvers	2	917.308	458.654	24.80	.05
Days	4	117.339	29.335	1.87	N.S.
Subjects	5	135.386	27.077	-	-
Man. x Day	8	133.996	16.750	0.99	N.S.
Man. x Sub.	10	184.936	18.494	-	-
Day x Sub.	20	313.438	15.672	-	-
Man. x Day x Sub.	40	673.857	16.846	-	-

TABLE 11

ANOVA - T & B Scan Rate

SV	df	SS	MS	F	p less than
Total	89	4797.580	-	-	-
Maneuvers	2	808.215	404.107	4.47	.05
Days	4	49.929	12.482	0.32	N.S.
Subjects	5	1225.658	245.132	-	-
Man. x Day	8	99.686	12.461	0.54	N.S.
Man. x Sub.	10	903.637	90.364	-	-
Day x Sub.	20	783.245	39.162	-	-
Man. x Day x Sub.	40	927.211	23.180	-	-

TABLE 12

Significant Differences Betwen Maneuvers (Scan Rate)

ALT	Cruise higher than ITO or ILS, ITO higher than ILS
VSI	ILS higher than CRUISE or ITO
AH	None
RMI	None
OBS	ILS higher than Cruise or ITO
AS	CRUISE higher than ITO or ILS
T&B	CRUISE higher than ILS

ANOVA Tables for Mean Dwell Time

TABLE 13

ANOVA - OBS Mean Dwell Time

SV	df	SS	MS	F	P less than
Total	89	6992194.000	-	-	-
Maneuvers	2	2625380.000	1312690.000	14.20	.05
Days	4	80405.000	20101.250	0.31	N.S.
Subjects	5	265917.000	53183.398	-	-
Man. x Day	8	108919.000	13614.875	0.33	N.S.
Man. x Sub.	10	924491.000	92449.102	-	-
Day x Sub.	20	1316811.000	65840.547	-	-
Man. x Day x Sub.	40	1670271.000	41756.773	-	-

TABLE 14

ANOVA - VSI Mean Dwell Time

SV	df	SS	MS	F	P less than
Total	89	3763450.000	-	-	-
Maneuvers	2	388644.000	194322.000	7.30	.05
Days	4	230606.000	57651.500	1.39	N.S.
Subjects	5	520958.000	104191.602	-	-
Man.x Day	8	344192.000	43024.000	1.45	N.S.
Man.x Day	10	266056.000	26605.600	-	-
Day x Sub.	20	828232.000	41411.602	-	-
Man.x Day x Sub.	40	1184762.000	29619.051	-	-

TABLE 15

ILS %TT

Subject	AH	RMI	OBS
1	12.4	21.9	29.5
2	6.9	24.2	31.6
3	9.1	32.2	22.3
4	33.9	23.8	11.4
5	20.4	24.7	16.6
6	38.8	20.8	10.5
Total	19.1	24.6	21.2

TABLE 16

%TT For Zone 1 Instruments During ITO

Subject	T&B	AH	RMI	ZONE 1
1	8.0	27.5	23.3	58.8
2	8.6	34.0	23.7	66.3
3	3.4	25.5	41.8	70.7
4	15.9	9.2	46.7	71.7
5	3.5	33.7	27.0	64.2
6	4.6	34.4	35.0	74.0
Total	7.6	26.8	33.4	67.8

TABLE 17

Percent of Total Time for Each Maneuver

INST	ITO	CRUISE	ILS
ALT	4.2	6.4	3.0
VSI	3.5	3.3	6.7
AH	26.8	28.5	19.1
RMI	33.4	13.2	24.6
OBS	1.7	1.1	21.2
AS	5.1	9.9	3.7
T&B	7.6	4.8	2.3
All Other Instruments	4.1	4.5	2.1

END

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